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Effects of Irregular Shelterwood System on Regeneration Frequency and Species Richness

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ABSTRACT

Sustainable Forest Management is the present need of flourishing forests of Nepal. This research was objectively carried out to assess and compare the regeneration status in controlled and regulated forest areas under irregular shelterwood system of Tilaurakot Collaborative Forest. For the regeneration assessment, circular plots of size 25 m^2 having radius 2.82 m were established to conduct forest inventory. Altogether 100 sample plots were laid out; 90 in regulated forest sub-compartments and 10 in controlled sub-compartment. Various statistical tests like Independent samples t test, Mann-Whitney U test, ANOVA and Tukey's b test were applied based on the characteristics of data set. The results showed that the number of seedlings and saplings per hectare were more in regulated compartment than in the controlled one. Similarly, sapling frequency was directly proportional with time such that in the regulated year 2014, 2015 and 2016 in regulated sub-compartment B3C2S8 was 4280/ha, 2040/ha and 840/ha respectively. However, the number of seedlings per hectare was found to be 13440, 7120 and 21040 in B3C2S8 i.e. number of seedlings was inversely proportional with the prolongation of time. Also, it was found that the effect of irregular shelterwood system on the forest has increases the species richness in regeneration layer and even promoted the threatened species like *Pterocarpus marsupium* and *Dalbergia laifolia*. The findings of this research will be helpful in the field of sustainable forest management in Nepal.

1. Introduction

Despite the increasing apprehension regarding the loss of tropical forests; and in spite of the substantial local and international efforts to find the solutions to the problem, the rate of deforestation is ever increasing in the tropics (Bawa & Seidler, 1998). To solve the problem various forms of natural forest management has been sought after; forest management is a fundamental process which in the due course leads to build up of the vigorous forest stand. (Tripathi and Khan, 2007). Regeneration, one of the significant factors of forest management, can be promoted by certain types of forest manipulation that leads to novel and more productive stages of forest growth. Because of its importance to forest management, the dynamics of regeneration after exploitation has received crucial attention in forest management scenario (Bazzaz, 1991). In Natural Forest Management (NFM) system trees are harvested in such a way that allows forest to regenerate naturally before the next harvesting is done and doesn't depend on extensive silvicultral operations (Bawa & Seidler, 1998). Natural regeneration in the forest ecosystem is essential for evolution as well (Ackzel, 1994).

Due to the increasing human population, pressure on forest ecosystems has exceeded the regeneration capacity of forest ecosystems which causes destruction of wilderness and loss of biodiversity (Eastwood et al., 2007) or manipulation of high-timber-value species such as mahogany in Central America (Lamb, 1966). Gayer was the first described the concept of the irregular shelterwood method and recommended that foresters should understand natural stand dynamics when implementing alternative silvicultural prescriptions (Silvy-Leligois,1953). Gayer's objectives were to promote the establishment of natural regeneration and the creation of the mixed species stands. One of the major objectives of irregular shelterwood system is to establish desirable species with an extended regeneration period than a regular system (Smith, 1986; Hannah, 1988; Lanie, 1994). It also induces the establishment of multispecies cohorts by opening canopy and fulfilling light requirements of the species (Kneeshaw & Bergeron, 1998; McCarthy 2001). Almost all of the districts of Terai in Nepal consist majority of mixed *Shorea robusta* (Sal) forests which are mostly old aged, over matured, diseased and hollow inside. There is inadequacy of proper management of seedling, sapling and poles mostly because protective perception of the people about forest rather than productive. A number of current issues related to extend, location, distribution and pattern of felling and its visible effects on regeneration and species composition can be investigated to develop sustainable forest management plan (Wahav, 2001). Therefore, this research was carried out to analyze and compare the effects of irregular shelterwood system in regeneration and species richness in a tropical forest of Nepal.

2. Materials and Methods

2.1 Study Site

Tilaurakot collaborative forest, situated in Kapilvastu district of Nepal, covers an area of 9427.48 ha as a single working circle (Fig.1). The forest is comprised of natural forest of *Shorea robusta* and *Termanalia tomentosa* as dominant species, in association with *Pterocarpus marsupium*, *Dalbergia latifolia*, *Acacia catechu*, *Bombax ceiba*, *Tectona grandis*, *Anogeissus latifolia* (Fig.2).

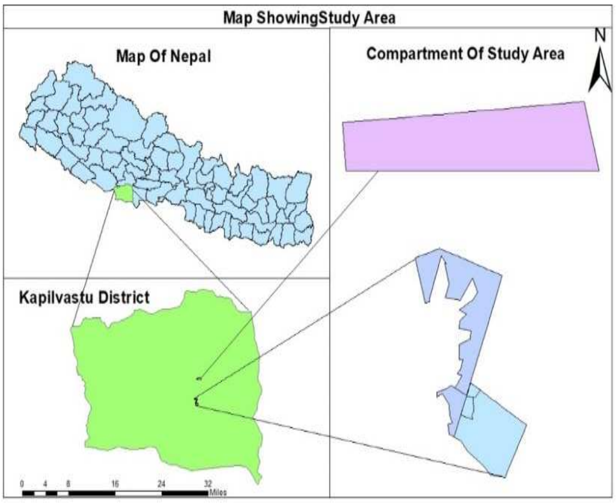

Figure 1. Map of the study Area

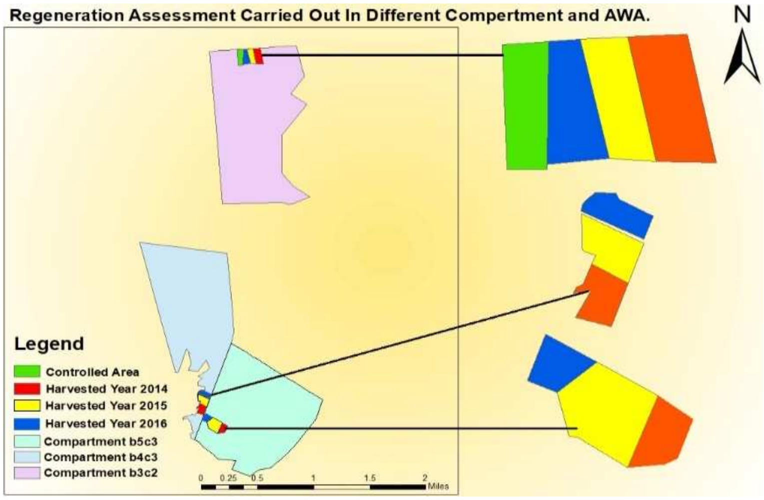

Figure 2. Regenration Assessment Carried out in different Sub- compartments of Tilaurakot Collaborative Forest

2.2. Sampling process

The sub-compartments B3C2S8, B4C3S8 and B5C3S4 were selected for the data collection; each forest compartments regulated in the year 2014, 2015 and 2016 as annual working area. The seedlings and saplings were enumerated in each of these sub-compartments regulated under irregular shelterwood system. In the same way, the part of sub-compartment **B3C2S8** was selected as controlled area and regenerations were counted. Systematic sampling was followed for data collection. The quadrates locations (longitude and latitude) were extracted with the help of ArcGIS 10.2. Ten sample plots of 25 m² (to attain accurate data) per annual working area on were allocated each regulated sub-compartment using fishnet tool of Arc GIS. In this way, altogether ninety sample plots were allocated on three regulated sub-compartments and ten sample plots were allocated on a controlled sub-compartment.

2.3 Data Analysis

After the regeneration count, the regeneration between and within regulated sub-compartments also with controlled sub-compartment were analyzed. For the statistical test, parametric test particularly One-way ANOVA and Tukey's b Post Hoc for three level factors and multiple comparisons were carried out. Similarly, Mann-Whitney test for two level factor was performed using statistical Package for Social Sciences (SPSS, version 20). Similarly, other software like Arc GIS 10.2, Microsoft excel and software for statistical computing and graphics R. were used for the data analysis.

3. Result

The results depict the status of regeneration after the regulation of forest by irregular shelterwood system and also gives the comparative study of regeneration with controlled area. Moreover, effect of time on regeneration and species richness are depicted in results.

3.1. Comparison of regeneration between regulated and controlled sub-compartments

The result demonstrates that in regulated sub-compartment (B3C2S8), the number of seedlings per hectare was 13867 while it was only 9120 seedlings per hectare in the controlled sub compartment. Similarly, in the same regulated sub-compartment saplings/ha was 2387 while it was 1240 saplings per hectare in the controlled plots. Similar results were observed in other two sub-compartments as well (Table 1).

Table 1. Regeneration Status between regulated and controlled sub-compartments

Regeneration	Regulated Sub-compartments			Controlled Plot
	B3C2S8	B4C3S8	B5C3S4	
Seedling (N/ha)	13867	11827	14307	9120
Sapling (N/ha)	2387	1880	4547	1240

Statistical analysis with the application of Mann-Whitney U test showed that there was significance difference in number of seedling and saplings between regulated site (B3C2S8) and controlled site at 5% level of significance (Table 2). However, no significant difference was seen between the regulated site (B4C3S8) and controlled site. The results in regulated site (B5C3S4) and controlled site showed that there was significant difference at 5% level of significance.

Table 2. Statistical Comparison of Regeneration between regulated and controlled plots with the application on Mann-Whitney U test.

Regeneration	Sub-Compartments		
	B3C2S8 and control plot	B4C3S8 and control plot	B5C3S4 and control plot
Seedling	0.006	0.130	0.006
Sapling	0.025	0.255	0.001

3.2. Relation between regeneration (seedling and saplings) with time

In the regulated sub-compartment B3C2S8, the number of seedlings in the area regulated in year 2016 was much higher i.e.: 21040/ha; however, it was only 13440 seedlings/ha in the area regulated in 2014 (as seedlings turned into saplings with passing time). In case of saplings, the chart shows exactly the reverse of the case of seedlings. The number of saplings was 840/ha in the forest area regulated in the year 2016 and it was 4280 saplings/ha in the forest area regulated in the year 2014 (Fig. 3).

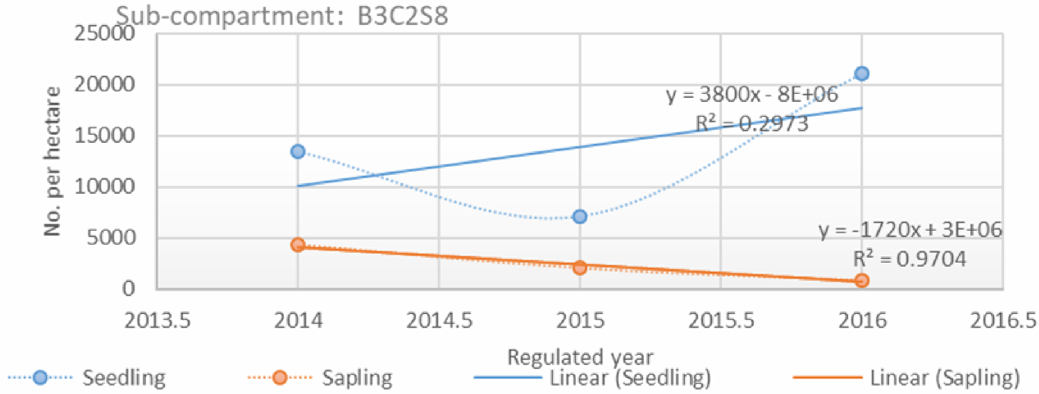

Figure 3. Chart showing the regeneration status (Seedlings/saplings) per hectare by numbers in sub-compartment B3C2S8 regulated in three different year (2014, 2015 and 2016)

Similarly, the chart below shows that in sub-compartment B4C3S8 the number of seedlings was 12600/ha in the area regulated in year 2016 while it was 7640/ha in the area regulated in 2014. However sub-compartment B3C2S8 the number of saplings is reverse to the pattern of seedlings, that is, the number of saplings is in the forest are regulated in the year 2015 is 2600/ha and in the year 2014 is 7640/ha. There were no saplings found in the area regulated in the year 2016 (Fig. 4).

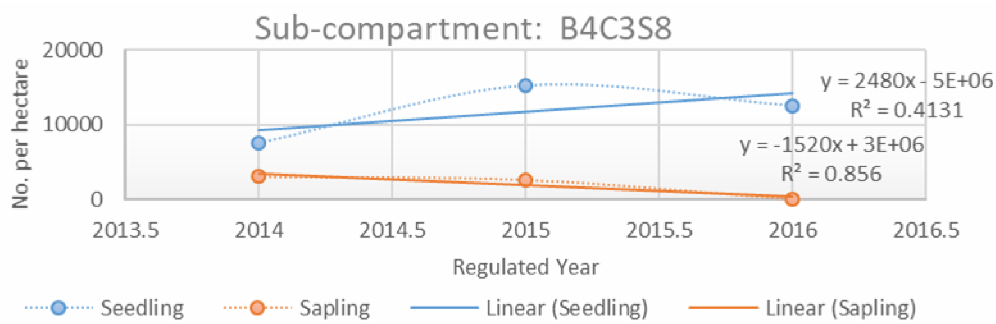

Figure 4. Chart showing the regeneration status (Seedlings / saplings) per hectare by numbers in sub-compartment B4C3S8 regulated in three different year (2014, 2015 and 2016)

As other two forest sub-compartments, in sub-compartment B5C3S4, the number of seedlings was highest in the area regulated in the year 2016, that is, 19560 seedlings/ha while it was 4200/ha in the area regulated in 2014 in the. Whereas, in case of saplings, unlike the other sub-compartments, the chart below shows that the number of sapling was 5000/ha in the year 2016 but it was only 4400/ha in the year 2014; even after the prolonged time of 3 years in that sub-compartment B5C3S4 (Fig. 5).

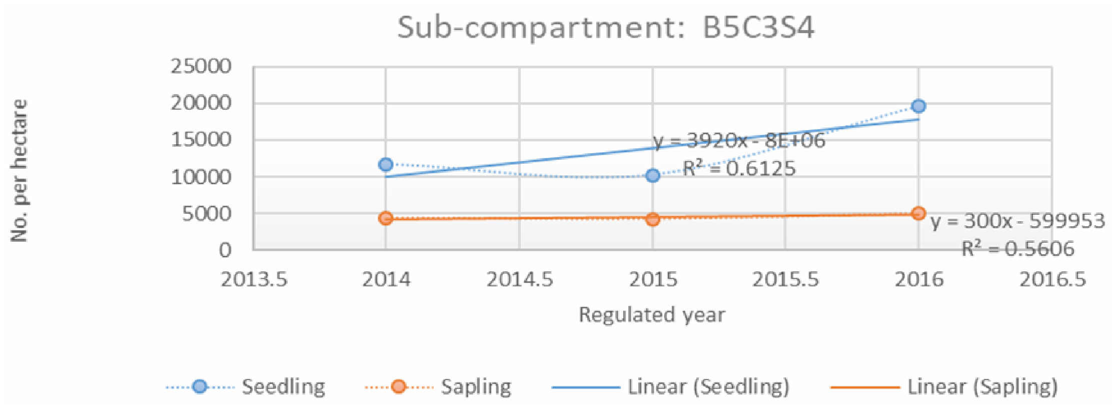

Figure 5. Chart showing the regeneration status (Seedlings / saplings) per hectare by numbers in sub-compartment B5C3S4 regulated in three different year (2014, 2015 and 2016)

With the application of one-way ANOVA: Post Hoc multiple comparison test, it was found that, there was significant difference in the seedlings and saplings in three sub compartments B3C2S8, B4C3S8 and B5C3S4 by number, regulated in the year 2014, 2015 and 2016.

3.3. Evaluation of species richness in the sub-compartments regulated in different years and its comparison with controlled sub-compartment

The species accumulation curves were drawn for all the regulated forest in the year 2014, 2015, and 2016 and unregulated forest as well. The curve in figure 6 shows that in regulated sub-compartment B3C3S8, the species richness of seedling in area regulated in the year 2014, 2015 and 2016 was 6 species, 4 species and 4 species respectively. However, the controlled area seemed to have almost equal species richness as in the area regulated in the year 2014 i.e. 6 species. In case of sapling, the species richness was lower in the area that was regulated in the year 2016 and control area i.e. 2 species. Whereas, the area where the annual working area was carried out in the year 2014 and 2015 has found to have higher species richness of 5 species.

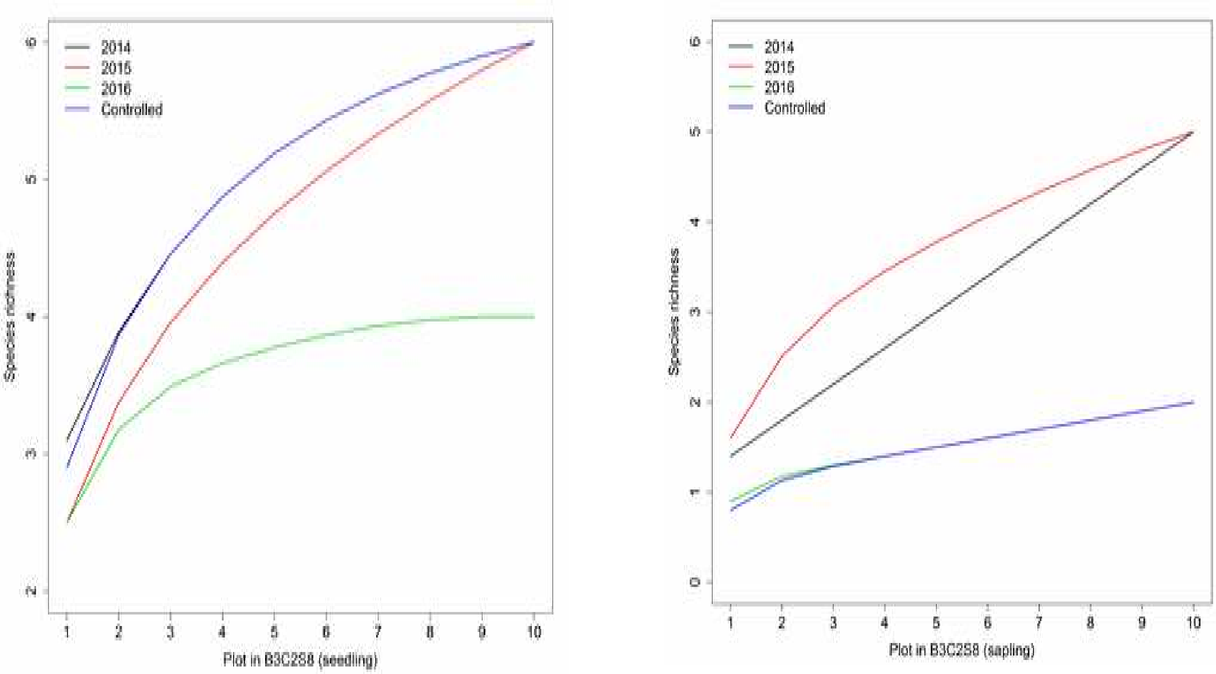

Figure 6. Curve showing spp. accumulation pattern in sub-compartment regulated in different year (B3C2S8) vs. controlled area

In sub-compartment B4C3S8, in case of seedling, the species richness was higher in the control area and regulated area in the year 2014 (6 species) in comparison to the area regulated in year 2016 (5 species). Similarly, in case of sapling, there was no regeneration in the controlled plot. Nevertheless, in the regulated where canopy was opened by the application of irregular shelterwood system, the saplings were able to grow in a natural way; species richness increased from 1 to 4 in the forest area regulated in the year 2014 (Fig. 7).

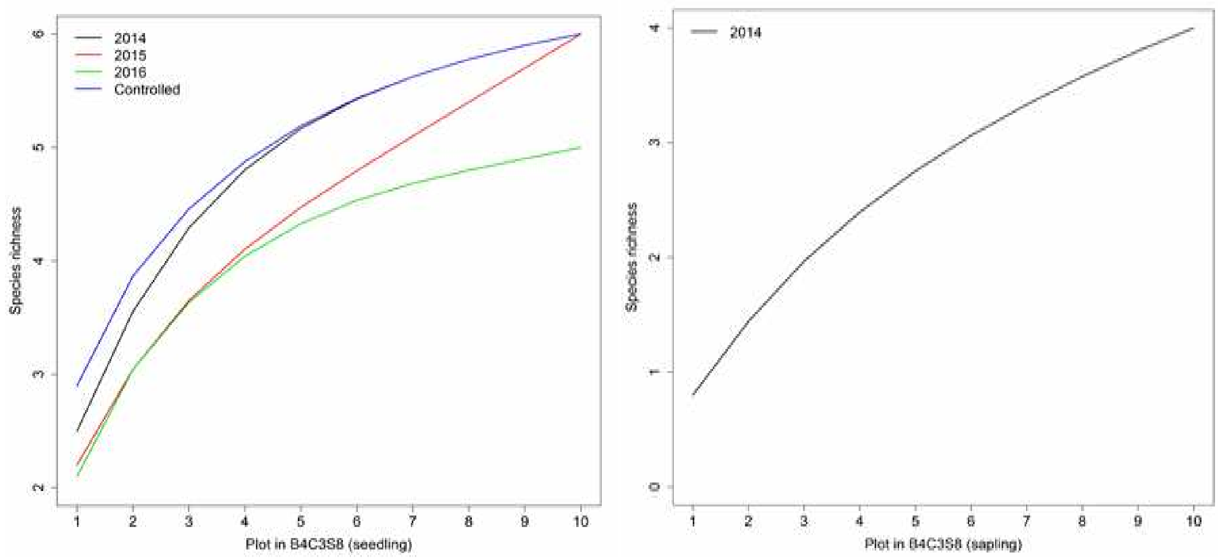

Figure 7. Curve showing species accumulation pattern in sub-compartment regulated in different year (B4C3S8) vs. controlled area.

In sub-compartment B5C3S4, the richness of species among seedling was found to be higher in the area regulated area in the year 2014 (12 species) followed by the area regulated in the year 2015 (8 species), area regulated in the year 2016 and controlled area (5 species) recorded from the 10 sample plots on each regulated and controlled area. The accumulation curve below shows that, the richness of sapling species was higher in the area regulated in the year 2014 (4 species) followed by the regulated area in the year 2015 (3 species), and 2016 (3 species) and controlled area (2 species) (Fig.8).

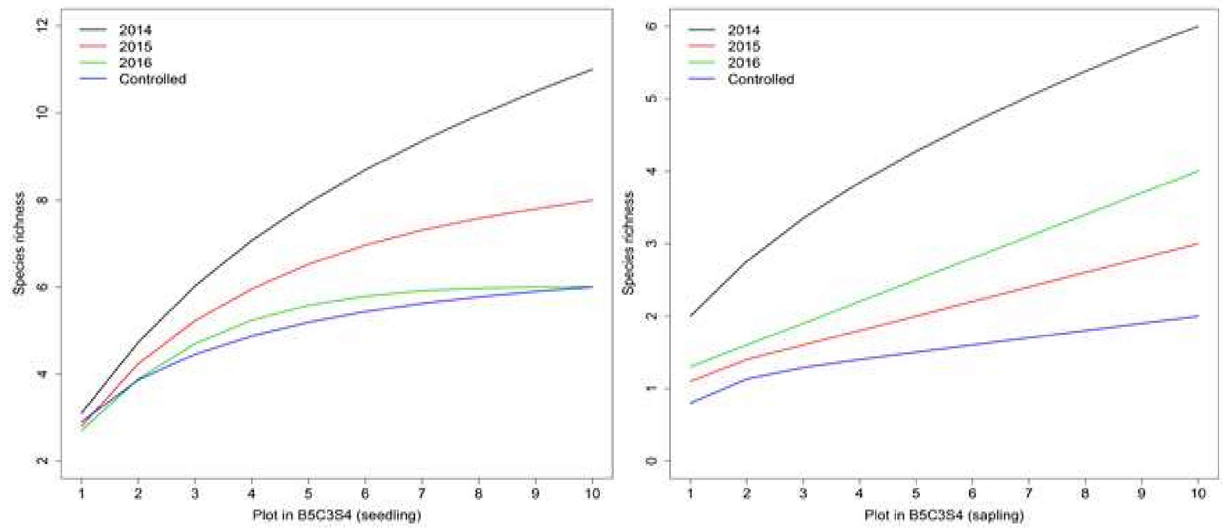

Figure 8. Curve showing regeneration species accumulation pattern in sub-compartment regulated in different year (B5C3S4) vs. control area

3.4 Comparative descriptive analysis of regeneration status

Descriptive statistics were also calculated to find the mean, median and standard deviation value of different species regenerating in the selected forest sub-compartments. These statistics provides the basis for detailed analysis for the difference between the regeneration pattern in the regulated and controlled area and their relations with time.

Table 3. Sub compartment and species wise descriptive analysis of seedlings and saplings including controlled.

Regulated year	2014				2015				2016			
B3C2S8												
Regeneratioin type					Sapling							
Species	**Mean±SE**	**SD**	**Min**	**Max**	**Mean±**	**SD**	**Min**	**Max**	**Mean±**	**SD**	**Min**	**Max**
Terminalia tomentosa	1±0		1	1	1.5±0.5	0.7	1	2				
Schleichera trijuga	1±0		1	1	1±0		1	1				
Engeharbtia spicata							0	0	1±0		1	1
Other	3±0		3	3	1.66±0.33	0.81	1	3				
Cassia fistula	1±0		1	1	1±0		1	1				
Shorea robusta	10.1±1.78	5.64	2	21	6±1.59	3.89	3	13	2.5±0.56	1.6	1	5
Regeneratioin type					Seedling							
Terminalia tomentosa	1±0	0	1	1	2±0		2	2			0	0
Aegle marmelos	2±0		2	2	1.5±0.5	0.7	1	2			0	0
Eugenia jambolana	1±0	0	1	1	1±0		1	1	1.5±0.5	0.7	1	2
Schleichera trijuga	1.8±0.37	0.83	1	3	3.25±1.10	2.21	1	6	2.71±0.52	1.38	1	4
Other	3±0.90	2.86	1	10	3.14±0.55	1.46	1	5	2±0.36	0.89	1	3
Shorea robusta	29±3.57	11.13	12	43	13.7±2.68	8.48	6	33	49.2±5.04	15.94	24	66
B4C3S8												
Regeneratioin type					Sapling							
Pterocarpus marsupium	1±0	0	1	1			0	0	Nothing			
Acacia catechu	1±0		1	1			0	0				
Adina cordifolia	1±0		1	1			0	0				
Other	2.5±1.5	2.12	1	4			0	0				
Cassia fistula			0	1	2±0		2	2				
Shorea robusta	7.22±2.23	6.7	1	20	7.87±0.89	2.53	3	11				
Regeneratioin type					Seedling							
Aegle marmelos			0	0	1±0		1	1			0	0
Pterocarpus marsupium	1±0	0	1	1			0	0	1±0		1	1
Eugenia jambolana	1±0	0	1	1	3±0		3	3	2.2±0.58	1.3	1	4
Adina cordifolia	1±0		1	1			0	0			0	0
Schleichera trijuga	1.4±0.24	0.54	1	2	2.5±0.86	1.73	1	5	2.33±0.88	1.52	1	4
Other	1.5±0.5	1	1	3	2.4±0.50	1.14	1	4	2.33±0.88	1.52	1	4
Shorea robusta	17.21±4.71	14.9	1	44	35.4±7.77	24.59	5	81	32.11±106	31.97	7	102
Dalbergia latifolia			0	0	1±0		1	1			0	0
B5C3S4												
Regeneration type					Sapling							
Terminalia tomentosa	1.6±0.4	0.89	1	3	1±0		0	0	1±0		1	1
Pterocarpus marsupium	1±0	0	1	1			0	0			0	0
Acacia catechu			0	0			0	0	1±0		1	1
Schleichera trijuga	1±0		1	1			0	0			0	0
Engeharbtia spicata			0	0			0	0	1±0		1	1
other	2±0		2	2			0	0			0	0
Cassia fistula	2±0		2	2	1±0		1	1			0	0
Shorea robusta	9.5±0.85	2.71	5	13	11.55±1.01	3.04	6	16	12.2±3.71	11.74	5	45
Regeneration type					Seedling							
Terminalia tomentosa	1.6±0.4	0.89	1	3	1±0	0	1	1			0	0
Aegle marmelos	1±0		1	1	1±0		1	1			0	0
Pterocarpus marsupium	2±1	1.41	1	3	4±1.52	2.64	1	6	2.33±0.66	1.15	1	3
Eugenia jambolana	1±0		1	1	1.5±0.5	0.7	1	2	1±0	0	1	1
Adina cordifolia	2±0		2	2	1±0		1	1			0	0
Acacia catechu	1±0		1	1			0	0			0	0
Schleichera trijuga	1.25±0.25	0.5	1	2	1.5±0.22	0.54	1	2	1.4±0.24	0.54	1	2
other	5.33±2.33	4.04	1	3	2±0.57	1	1	3	1±0	0	1	1
Shorea robusta	25.1±6.48	20.5	4	73	24.55±4.14	12.44	7	44	45.7±5.35	16.94	7	63
Dalbergia latifolia	1.5±0.5	0.7	1	2			0	0	3.25±0.110	2.21	1	6
Albezzia procera	1±0		1	1			0	0			0	0
Control area												
Sapling												
Terminalia tomentosa	1±0		1	1								
Shorea robusta	4.28±0.74	1.97	2	7								
Seedling												
Terminalia tomentosa	2±0		2	2								
Aegle marmelos	1±0	0	1	1								
Eugenia jambolana	1±0	0	1	1								
Schleichera trijuga	3.87±0.91	2.58	1	8								
other	1.8±0.37	0.83	1	3								
Shorea robusta	18±3.56	11.2	2	46								

4. Discussion

4.1. Comparison of regeneration status of harvested and controlled blocks

In a research carried out by Pourmajidian et al. (2010), the number of *Parrotia persica* seedlings increased by 13.2% from 1995 to 2005 in the northern forest of Iran after the application of uniform shelterwood system. In this research, number of seedlings per hectare was found to be more in the sub-compartment where irregular sheterwood system was applied, which is in the line of previous researches. Similarly, in another research conducted in Pennsylvania, the number of seedlings of *Quercus velutina* (Lam), *Quercus Montana* (chestnut), *Quercus rubra* (Wild, northern red oak), and *Quercus alba* (white oak) increased after the application of

Shelterwood System (Brose, 2011). The result of this study in is line with previous research the study carried out by Awasthi et al, 2015, who found that there was higher number of seedlings and saplings densities in the managed areas which could be the result of regeneration felling in managed area. In addition to that irregular shelterwood systems have proved to help in regenerating balsam fir-yellow birch stands (Suffice et al., 2015; Raymond et al., 2017).

4.2. Regeneration status between sub-compartments regulated in different years

It was found that the number of seedlings was inversely proportional to the time of harvest, i.e. the number of seedlings was highest in the area regulated in 2016 and lowest in the area regulated in 2014. On the other hand, the number of saplings was more in the area regulated in 2014 and least in the area regulated in 2016; it shows that the seedlings of area regulated in 2014 has turned into sapling now. It was found that, the relation of sapling frequency with time was directly proportional with time i.e. in the regulated sub-compartment B4C3S8 2014, 2015 and 2016, the number of saplings per hectare was found to be 3040, 2600 and 0 respectively whereas the number of seedling per hectare was found to be 7640, 15240 and 12600 respectively such that the seedling frequency was inversely proportional with the prolongation of time.

4.3. Comparison of species richness in harvested and controlled blocks

Lawton (1990) in his study ‘Canopy gaps and light penetration into a wind-exposed tropical lower mountain rain forest’ has reported that, natural disturbances to forest canopies create opportunities for the growth of nearby plants and establishment of new ones since the penetration of light is increased by canopy opening. Different species are successful in growing up in gaps of different size; therefore, the size of gap has as important influence on species composition and their spatial arrangement in the forest. Similarly, the open of canopy by irregular shelterwood system in this research has also increased species richness in the regulated sub-compartments.

A canopy opening after reduction of stand density was found to upsurge the abundance of early species (West and Osier, 1995) and prompt the proliferation of aggressive native and nonnative species (Franklin et al., 2002). The comparative study between the controlled and regulated forest distinctly shows that there was much difference between the regeneration (seedlings and saplings) by number as well as by composition. The canopy opening after the regulation of forest had made favorable condition for the different species including threatened species like *Pterocarcus marsupium* and *Dalbergia latifolia* as well as other common local species. Thus, irregular shelterwood system was found to be beneficial for the species conservation as well. The comparison between the regulated sub-compartment B5C3S4 and controlled area showed that, in case of seedling the species richness was increased from 6 to 11 and in case of sapling the species richness has increased from 2 to 6 after the application of irregular shelterwood system. Moreover, shelterwood system was found to be an excellent option for maintaining plant species diversity after logging (Poorbabaei1& Poor-Rostam, 2009).

5. Conclusion

The effect of irregular shelterwood system applied in Tilaurakot collaborative forest has showed positive result on regeneration. The seedlings and saplings are found to be in greater number in the regulated forest area than in controlled forest area. Similarly, the seedling frequency is inversely proportional to the prolongation of time; whereas sapling frequency is directly proportional to prolongation of time. This indicates that the number of seedlings were more in the area regulated in 2016 and least in the area regulated in 2014; the case was opposite for saplings. Similarly, the species richness was more in regulated forest area with the regeneration of threatened species like *Pterocarcus marsupium* and *Dalbergia latifolia* as well as other common species than the controlled forest area. In a nutshell, the intervention of scientific forest management by the application of irregular shelterwood system has constructive result in case of regeneration and species richness. Thus, such application of forest management is crucial for the productive and protective function of the forest.

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